TPC Distortions & Calibrations

estimated magnitudes and our ability to correct

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STAR TPC Review
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Outline

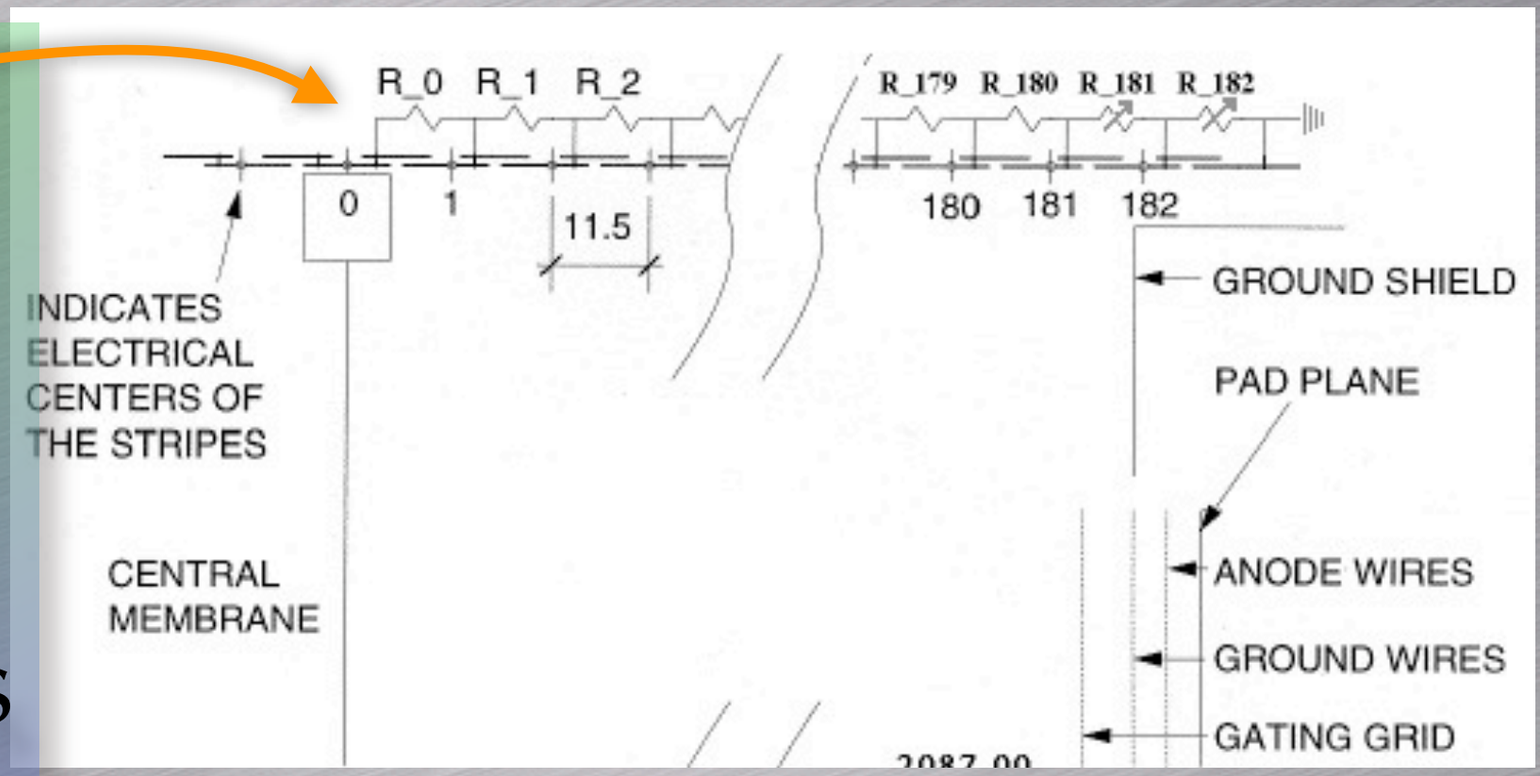
- Overview of the distortions
  - Description
  - Impacts of high luminosity (and aging)
- Correction techniques (calibrations)
  - Physics requirements
- Results (past and future prospects?)
- Summary

Distortions

- EM fields: non-uniformities are a reality
  - B field: small deviations (scale?), mapped, done
  - E field: surface & volume issues, static & volatile
    - The big three: (1) shorted field cage rings, (2) primary space charge, (3) gated grid ion leakage
- Electrostatics is known physics
  - Requirements: (1) model of the distortion, (2) measures/rulers (e.g. surveys, residuals) which keep pace with volatility

Field Cage Electrical Shorts

- Potential stepped from cathode to anode
- "Stripes" express potential inside the chamber

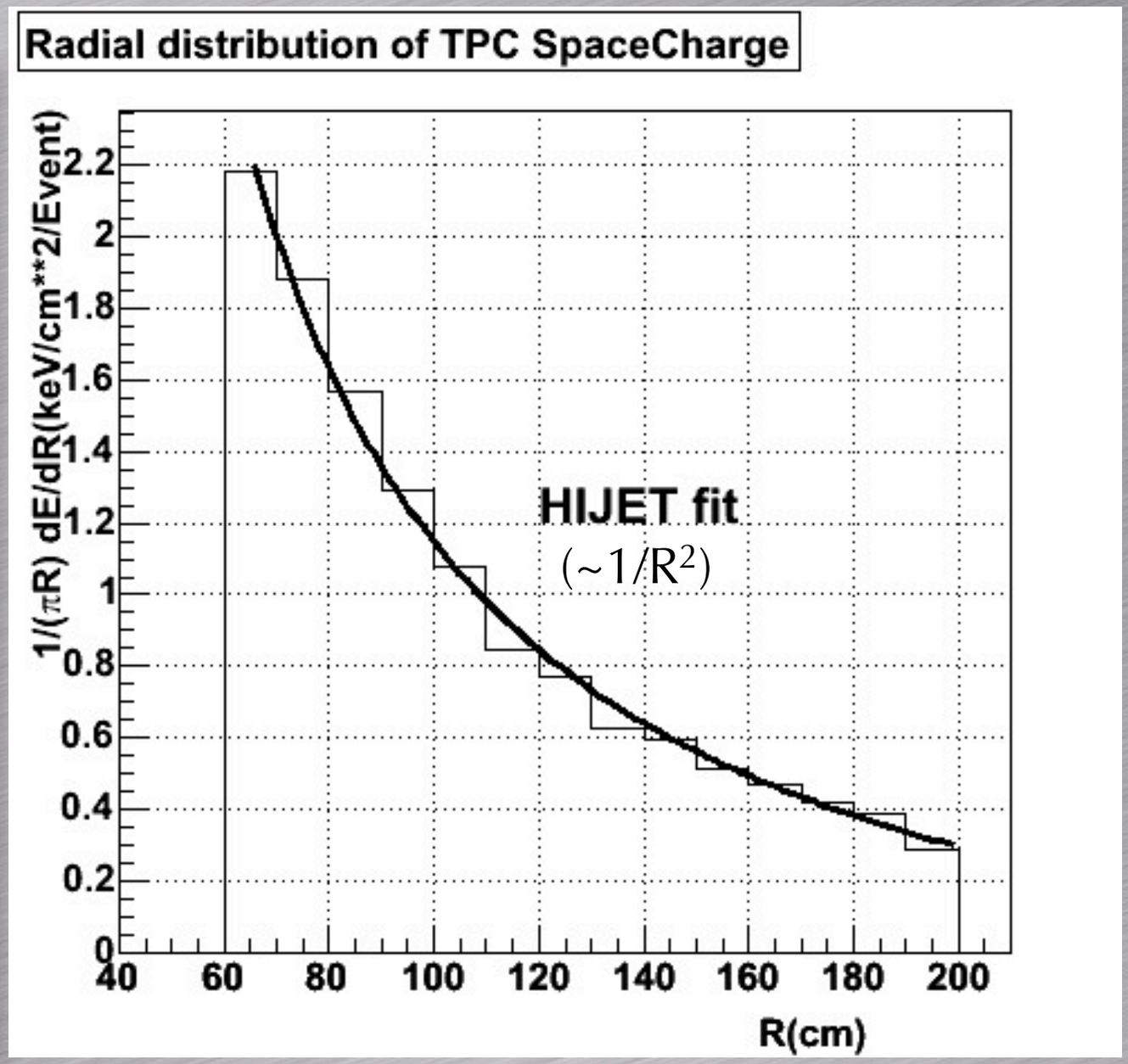


Field Cage Electrical Shorts

- Shorts have been a problem for several years now
  - Some fixed
  - Some not understood
- Worst threat comes from volatile shorting
  - Not a current problem
- Very unlikely a high luminosity issue
  - Unknown whether its an aging issue

SpaceCharge: model of charge

- HIJET model of "event shape" for 200 GeV AuAu collisions matches radial distribution of zerobias data well for much of the runs.



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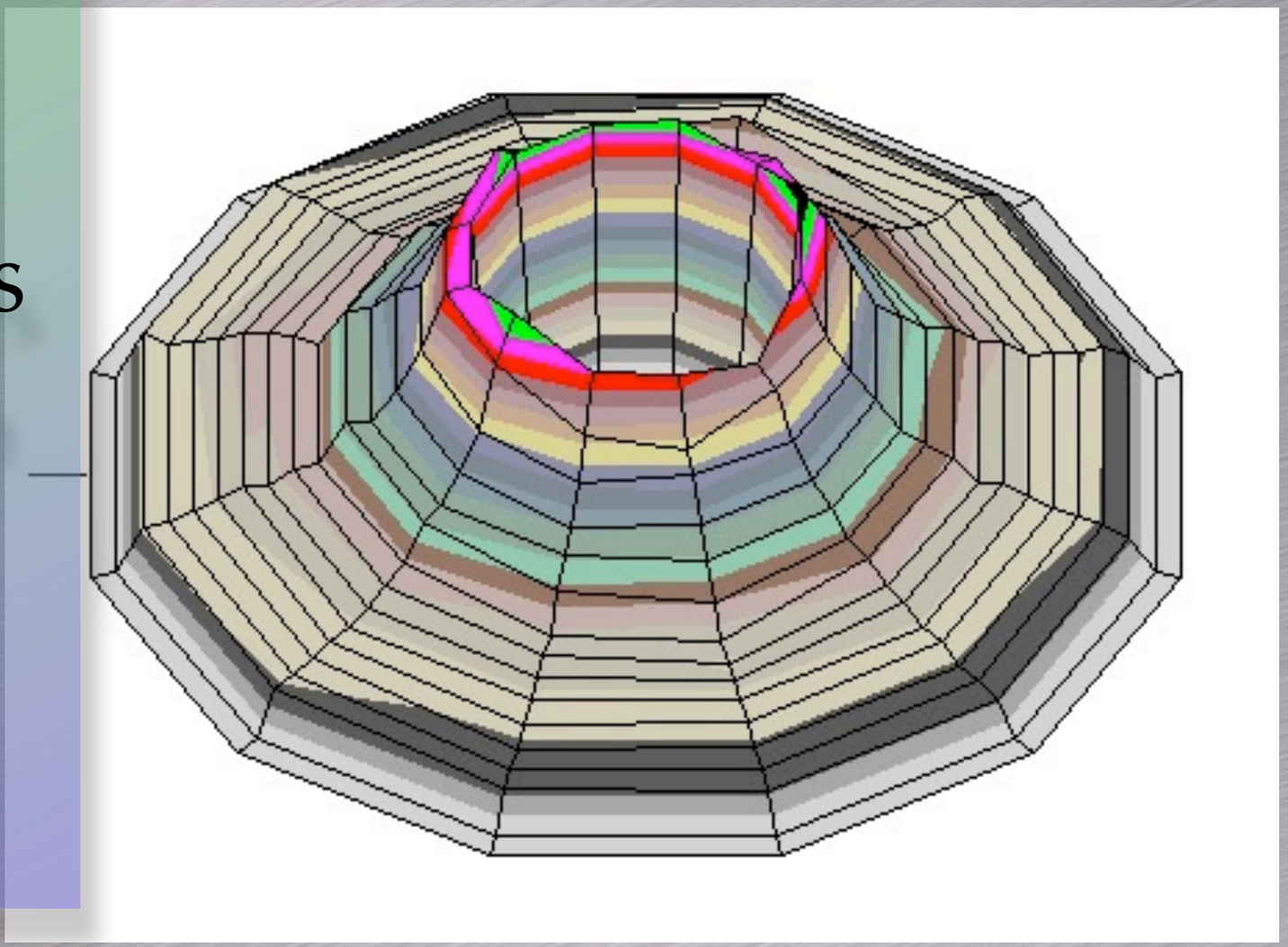
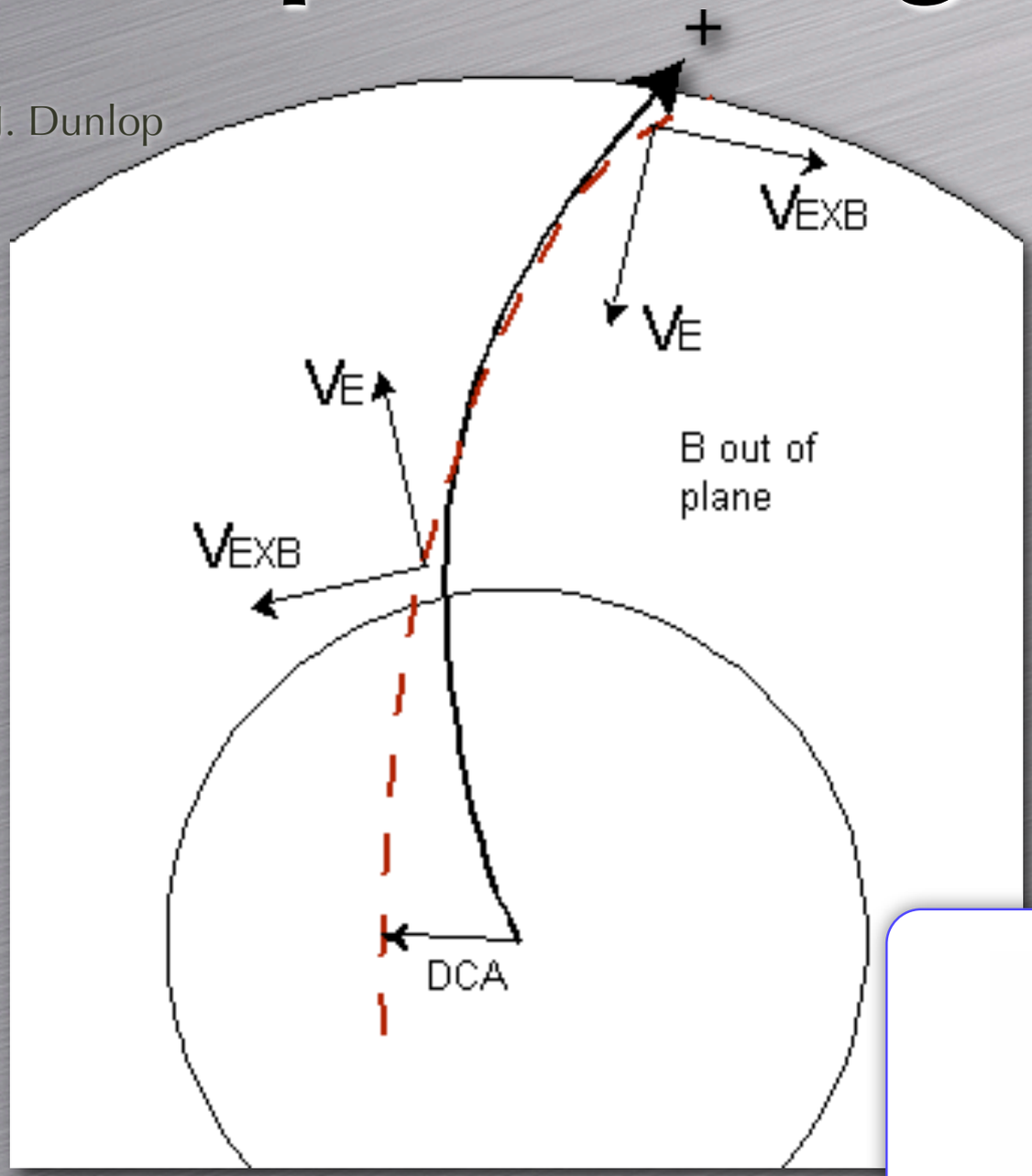


March 1, 2004 data

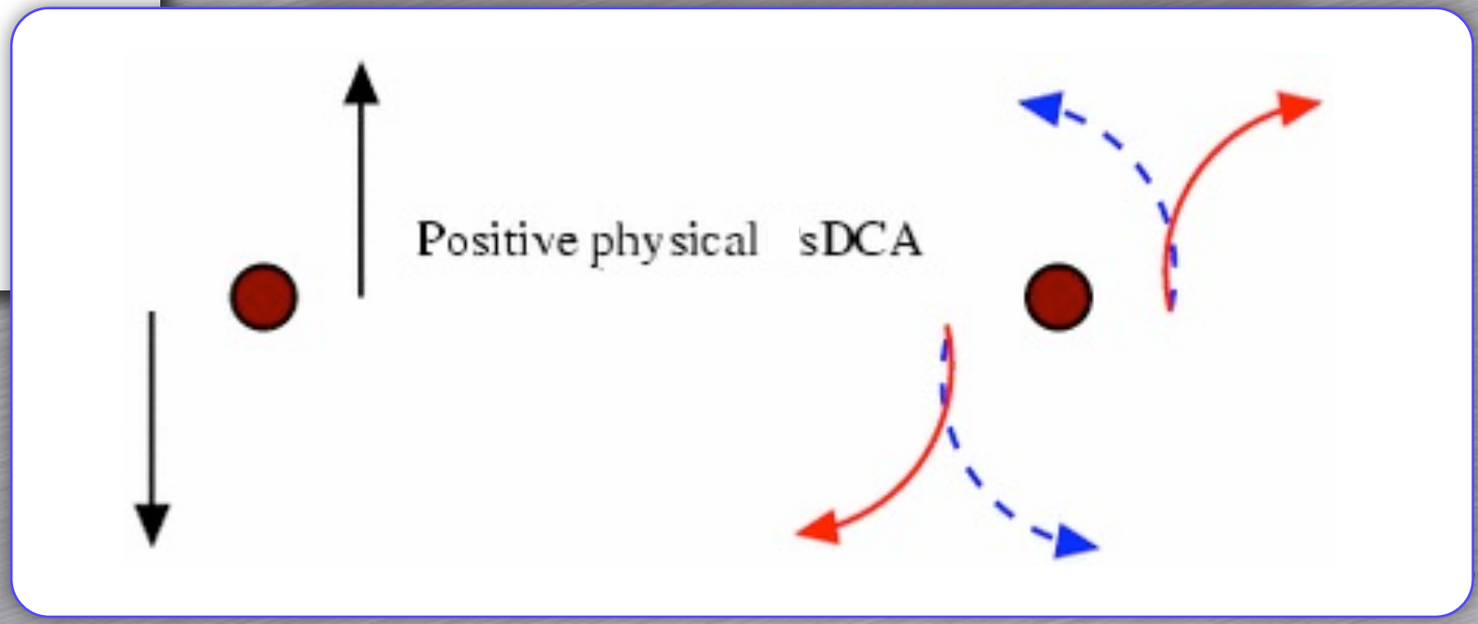
SpaceCharge effect on sDCA

J. Dunlop



- All tracks go the same direction (pos. or neg.)
- Track charge independence
- Field dependence

sDCA = signed distance of closest approach



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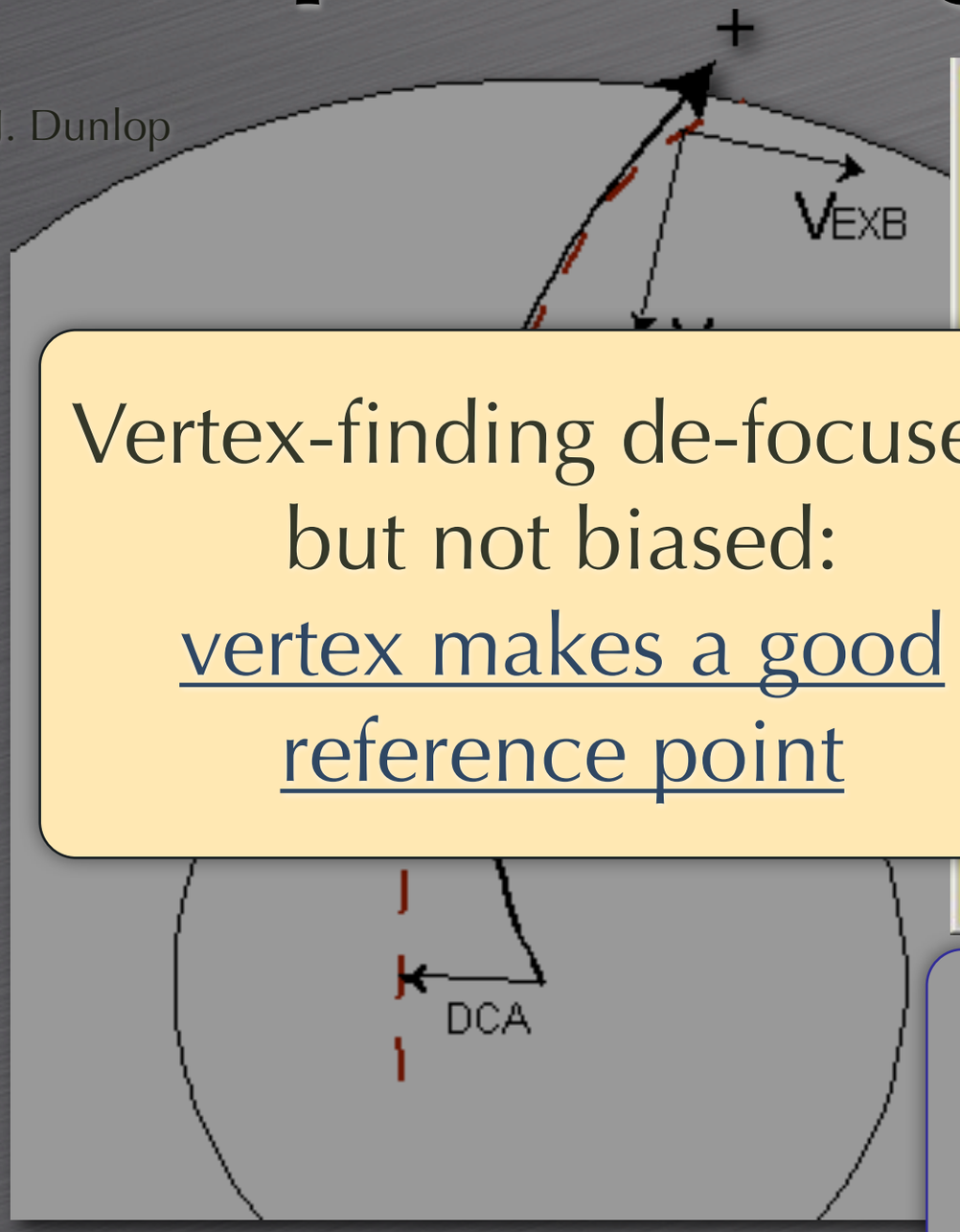
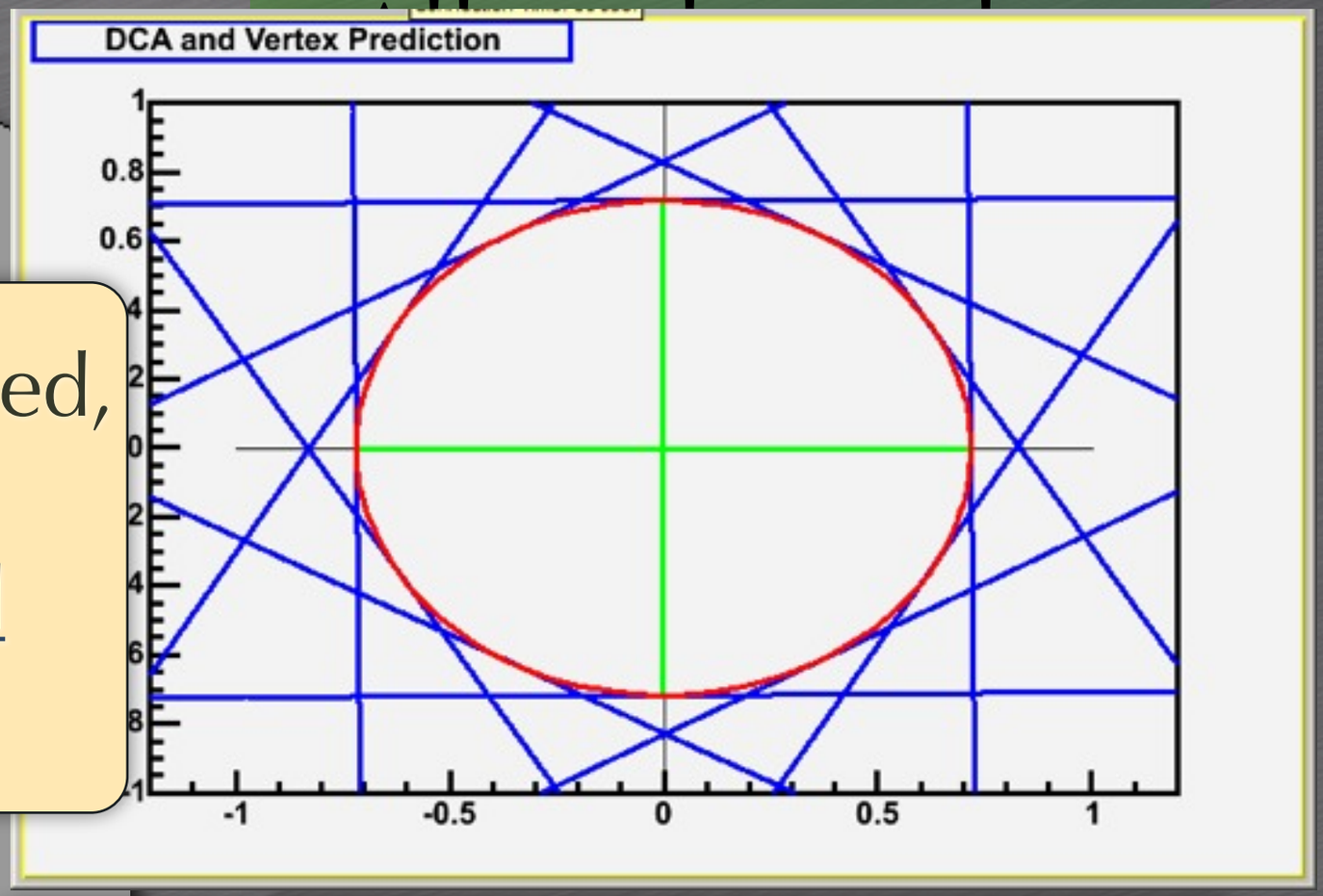
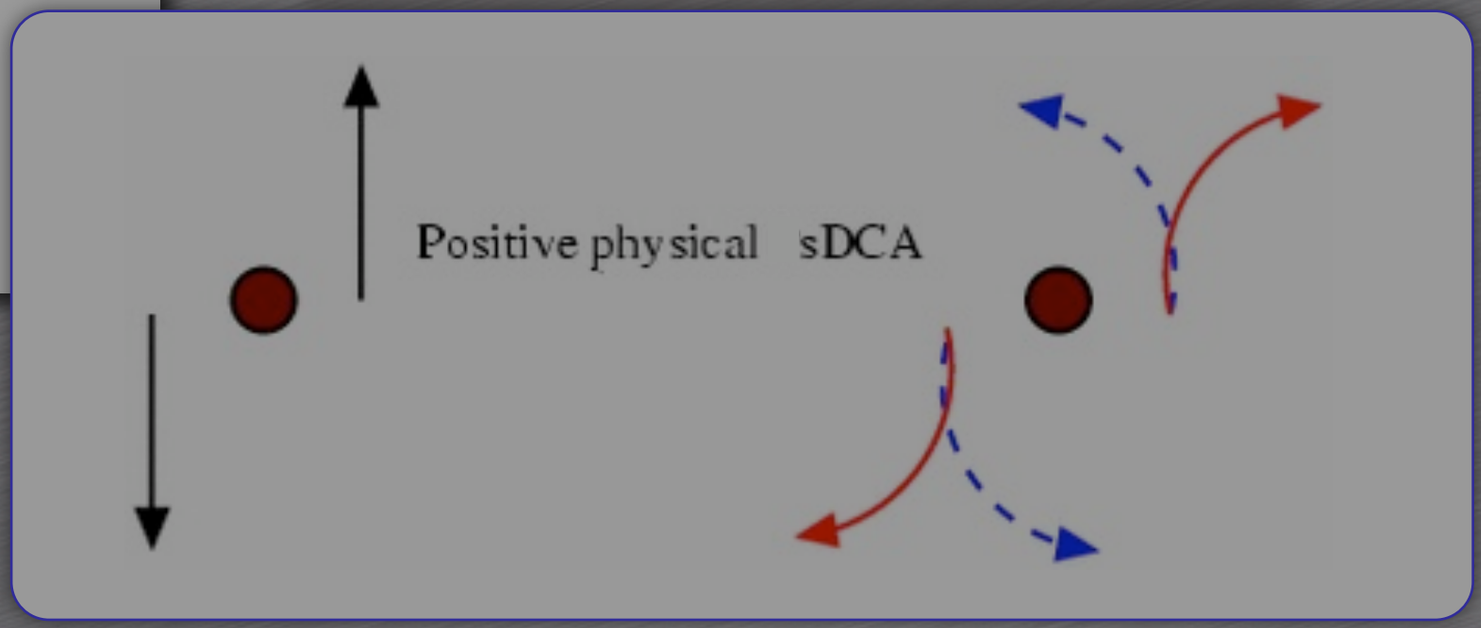




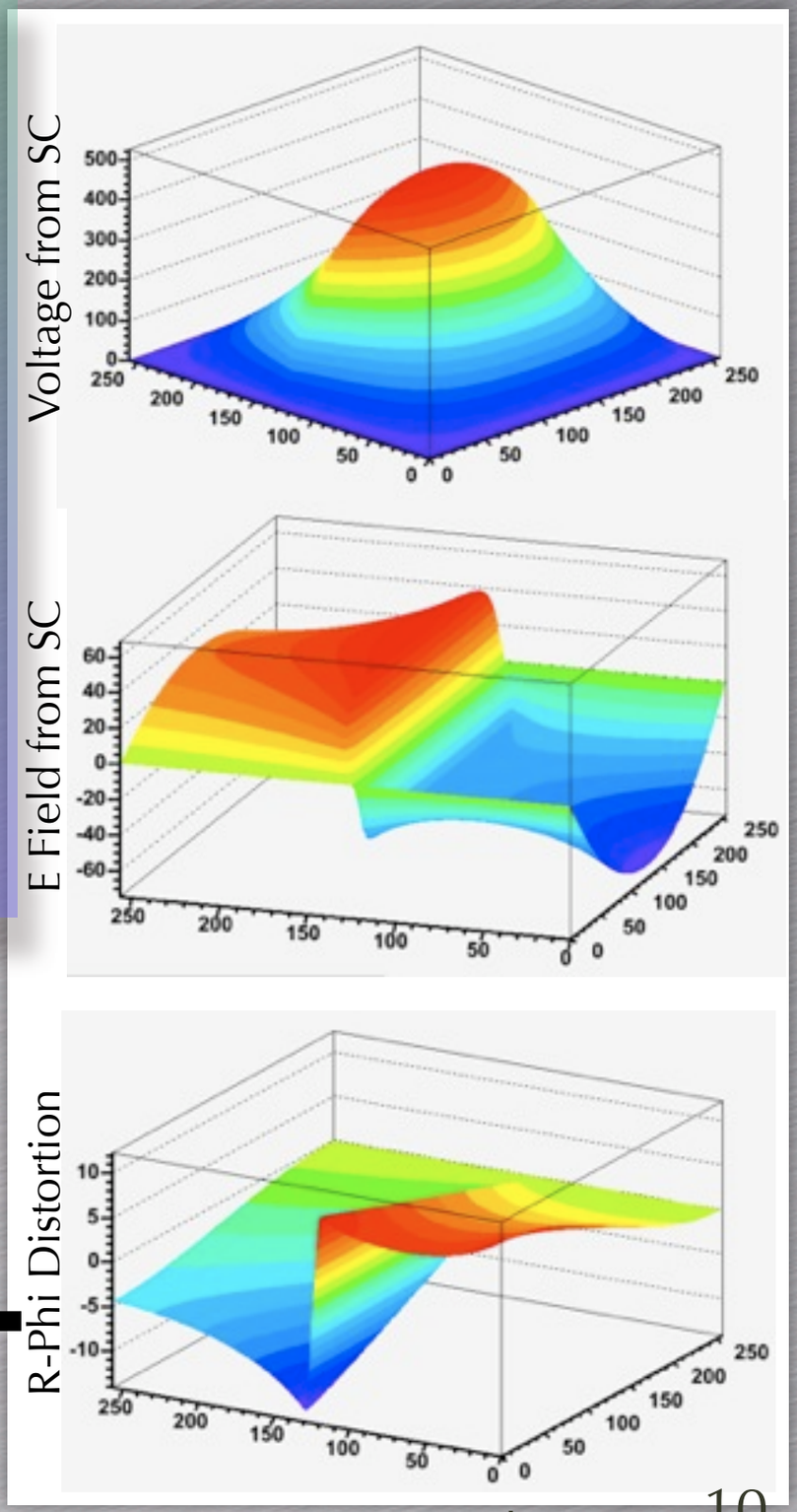
Vertex-finding de-focused, but not biased: vertex makes a good reference point

sDCA = signed distance of closest approach

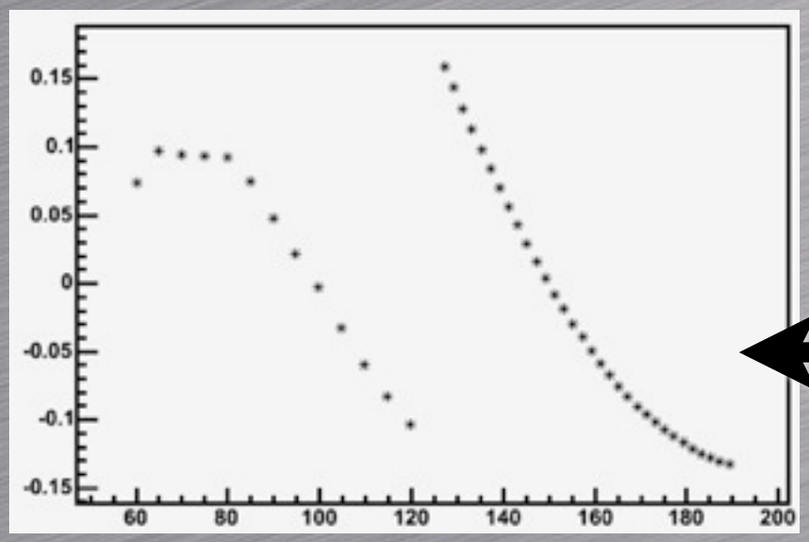


GridLeak Field Effects

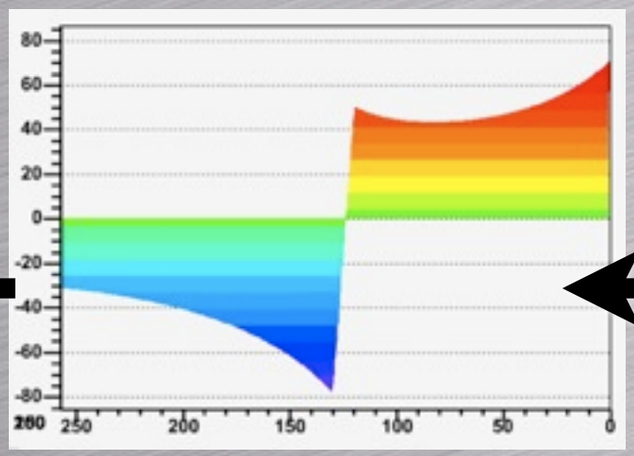
- Modeled sheets of charge
  - Relaxation done on custom 3D grid
    (plots assume Φ symmetry, but leak is 12-fold symmetry from grid shape)
  - E-field and distortion discontinuity at grid gap
- *GridLeak scales as SpaceCharge!*



Simulated residuals on a track



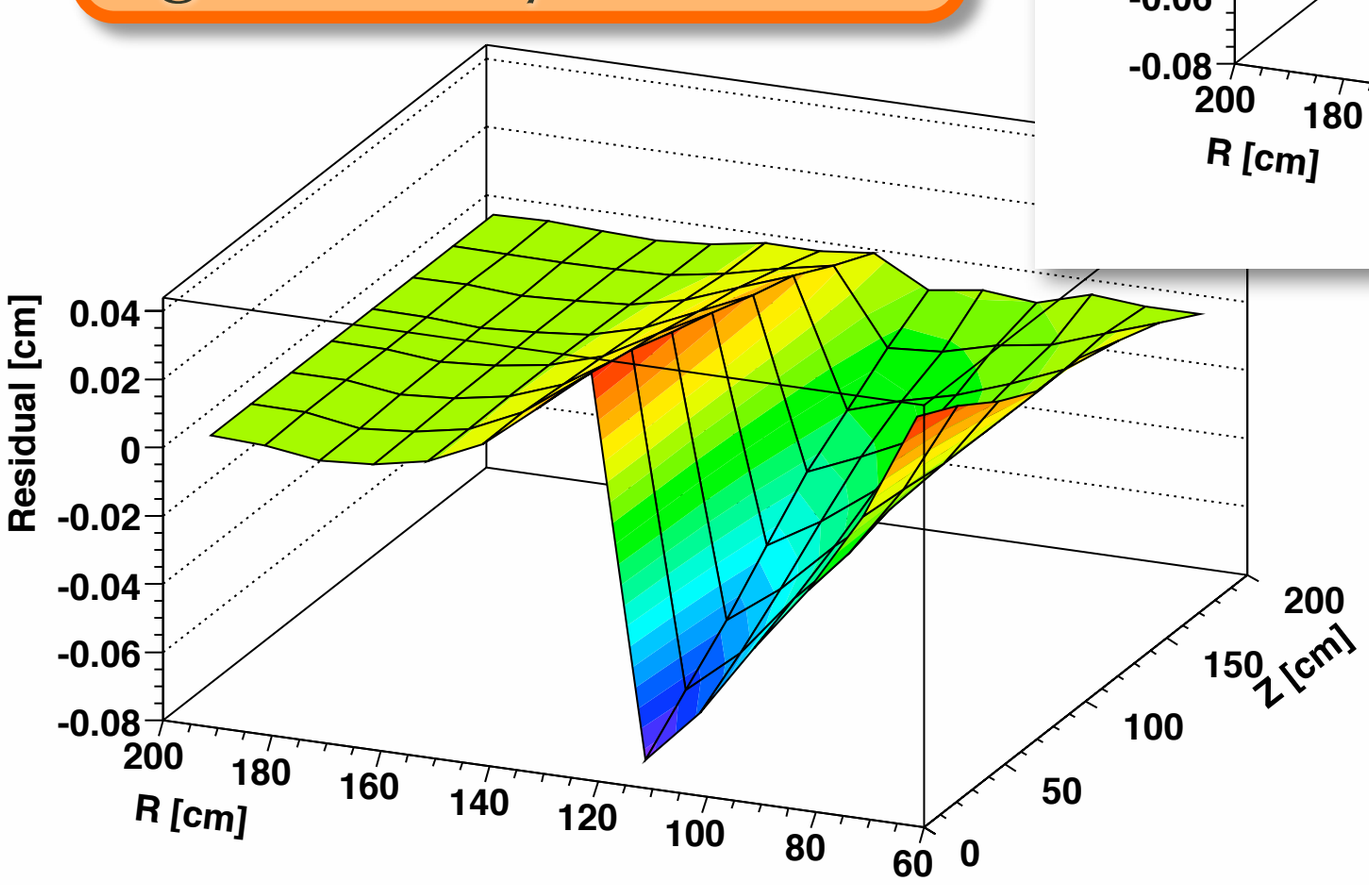
Distortion near CM

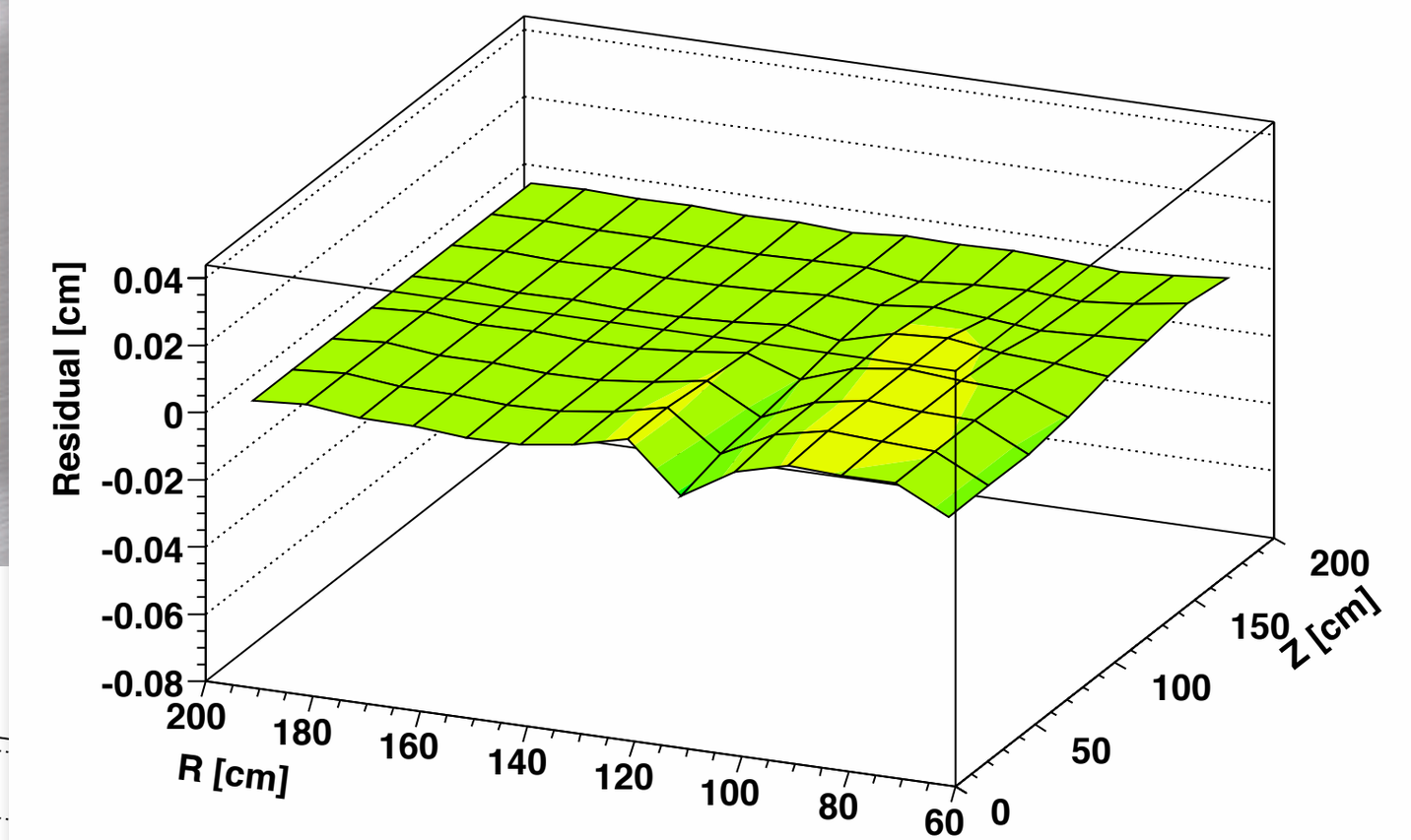


Applied GridLeak Correction

- Not perfect, but as good as design spec!

Distortions scale significantly reduced!



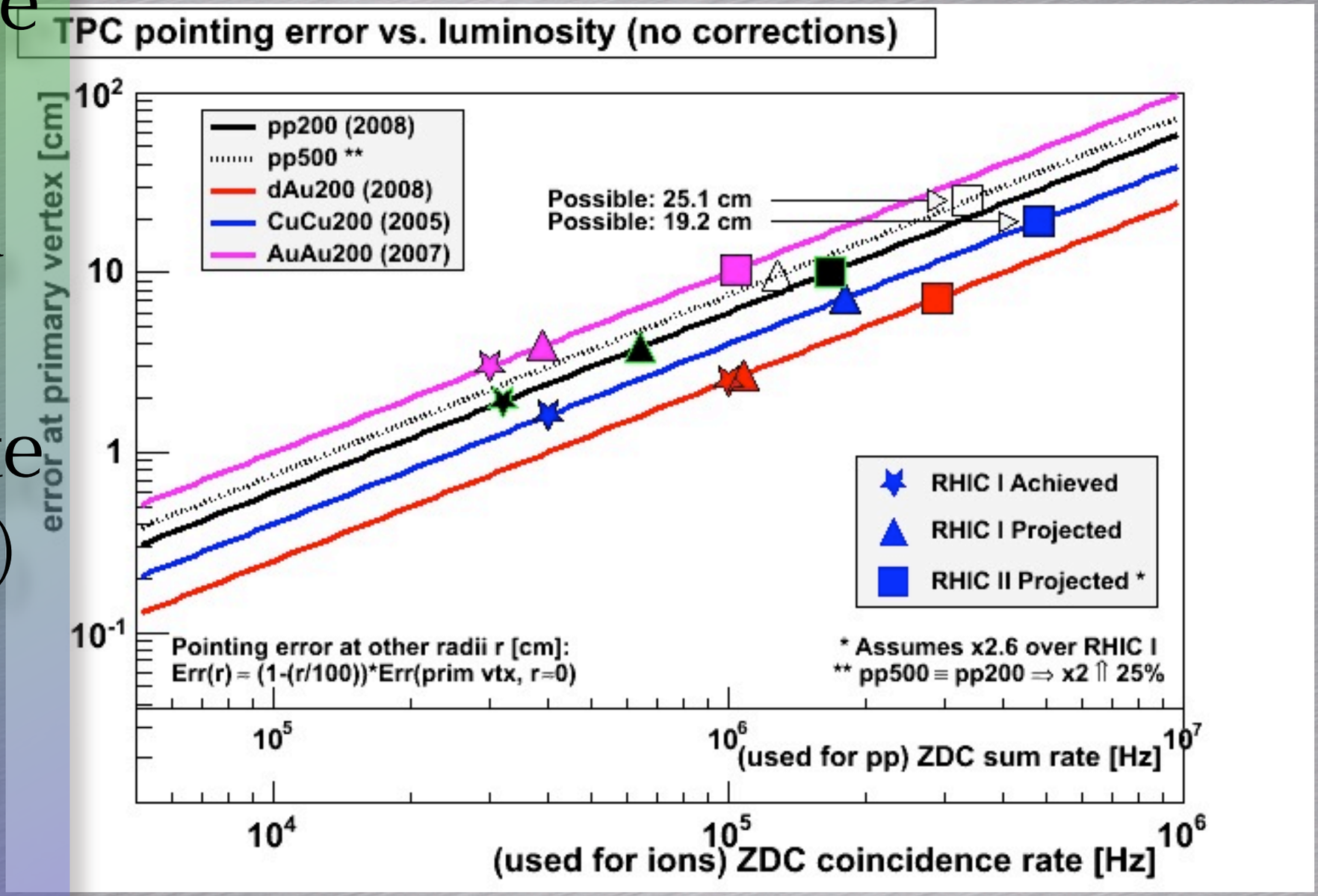


After

Before

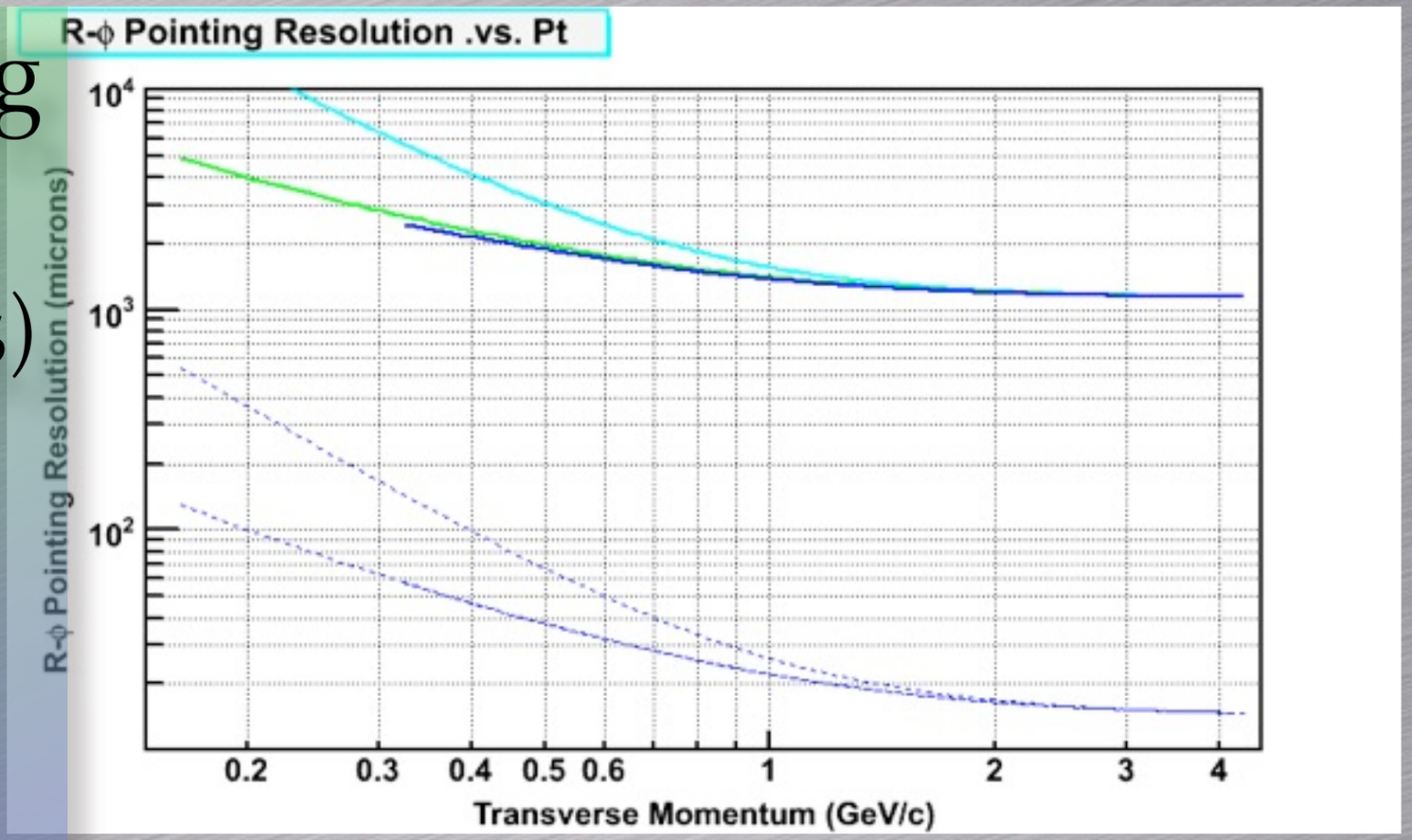
Projected pointing errors

- pp500 is the worst
  - Run 9 was a good test
- Intermediate ions (CuCu) perhaps worse than heavy ions (AuAu, UU?)



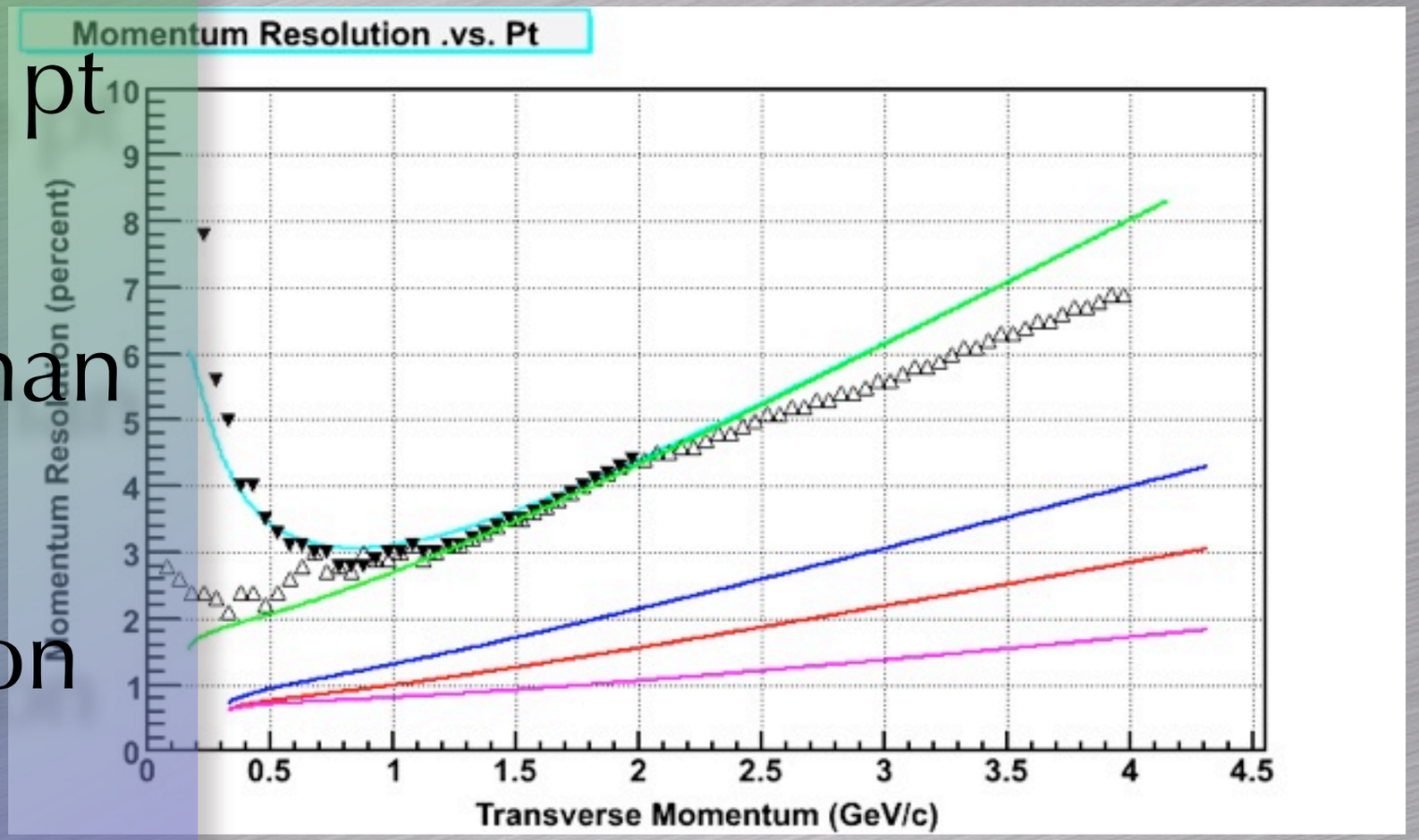
Pointing resolution

- Important for using inner (silicon tracking, upgrades)
- More Discussion



Momentum resolution

- Important for physics at high pt
- Biases can be more serious than smearing
- More Discussion



Distortion Corrections

Distortion	Approximate Scale [microns]	Correction Scale [microns]
Twist (E-B alignment)	800	50
IFC Shift	100	50
Clock (East-West rotation)	800	50
Padrow 13	400	50
B field shape	800	50
Shorted Ring	2000[A]	100[B]
Space Charge	up to 5000[C]	100-200[D]
Grid Leak	up to 2500[C]	100-200[D]
Unknown	100??? 300???	100??? 300???

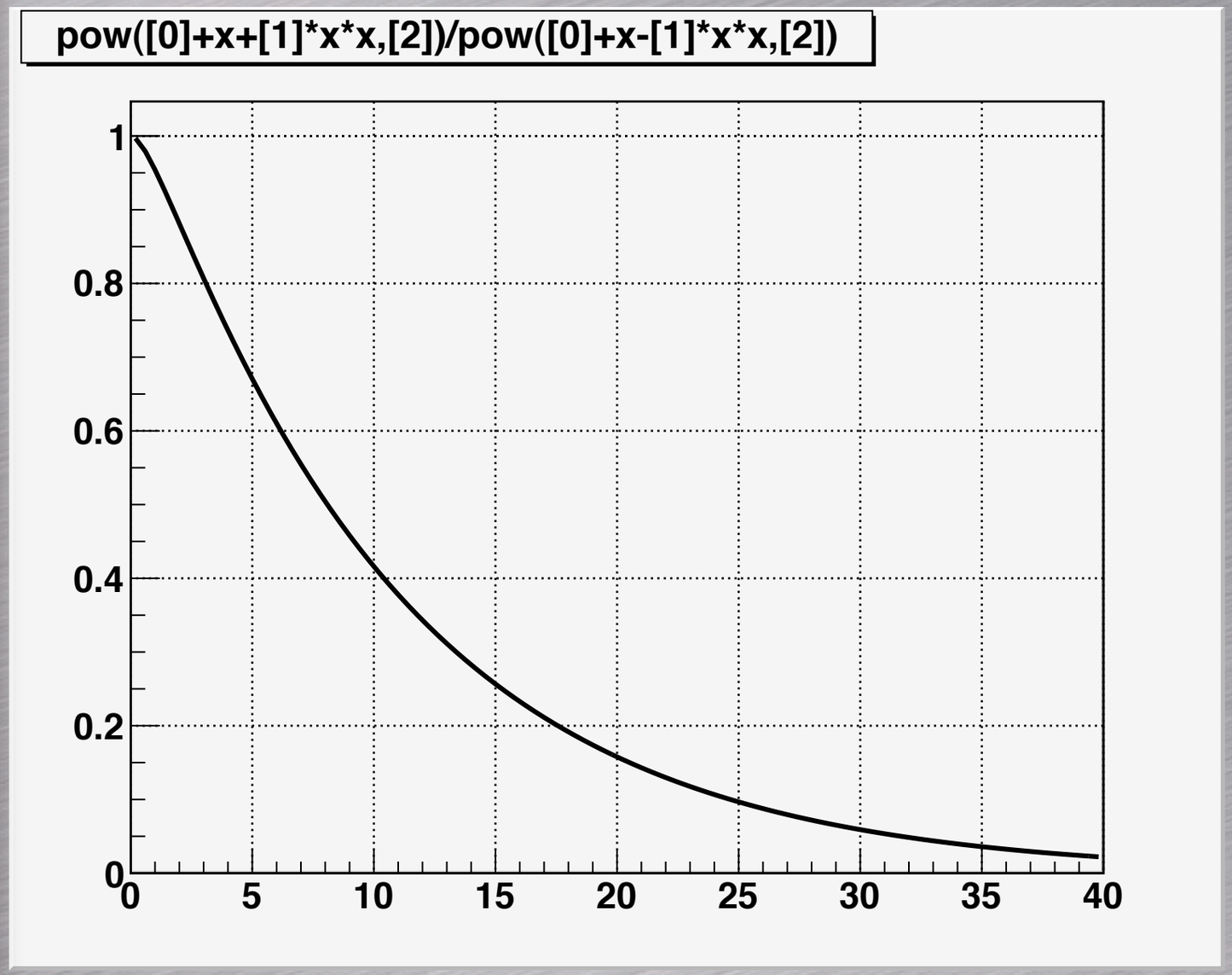
- Overall contribution to $\delta p_t/p_t \sim {}^1/_4\text{-}{}^3/_4\% * p_t$ for TPC-only tracks (primary vtx, silicon help)

A. Larger (up to 5000) without compensating resistor.
B. Known to be ~400 microns in a region of the TPC not used for physics.
C. Luminosity dependent
D. Dataset dependent

CDR design was ~1%*pt

Momentum biases

- A very small bias can lead to a large effect
  - h-/h+ with a mere 0.005*pt^2 bias
- More discussion



Calibration first steps

- Non-volatile calibrations must be completed first (e.g. internal alignment, and w.r.t. B field)
  - Necessitates low luminosity data
    - RHIC was unable to deliver this during pp500 this year.....the future?
- Field cage currents measure shorts
- sDCA and residuals tell us about the SpaceCharge and GridLeak

First steps to corrections

- Observables (sDCA) can tell you the distortion quantity (ions in the TPC due to SpaceCharge buildup + GridLeakage)
- Easy with "ideal" tracks
  - Little or no dependencies on reconstruction itself
  - Observable maps easily to distortion quantity
    - sDCA = C * f(Z) * (SpaceCharge + GridLeak)
  - Generally need many events for stats
    - Could be many *runs* for pp collisions!

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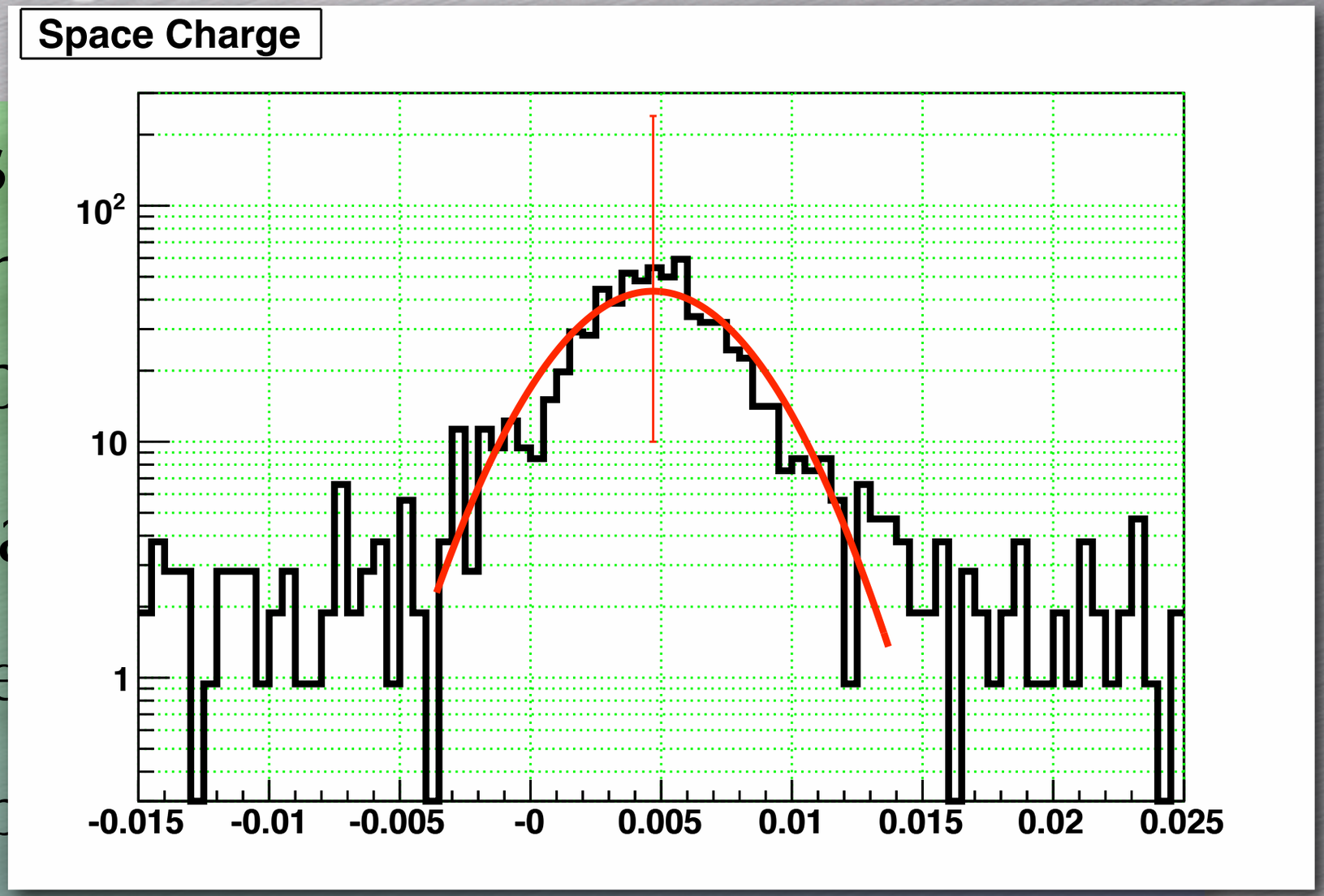
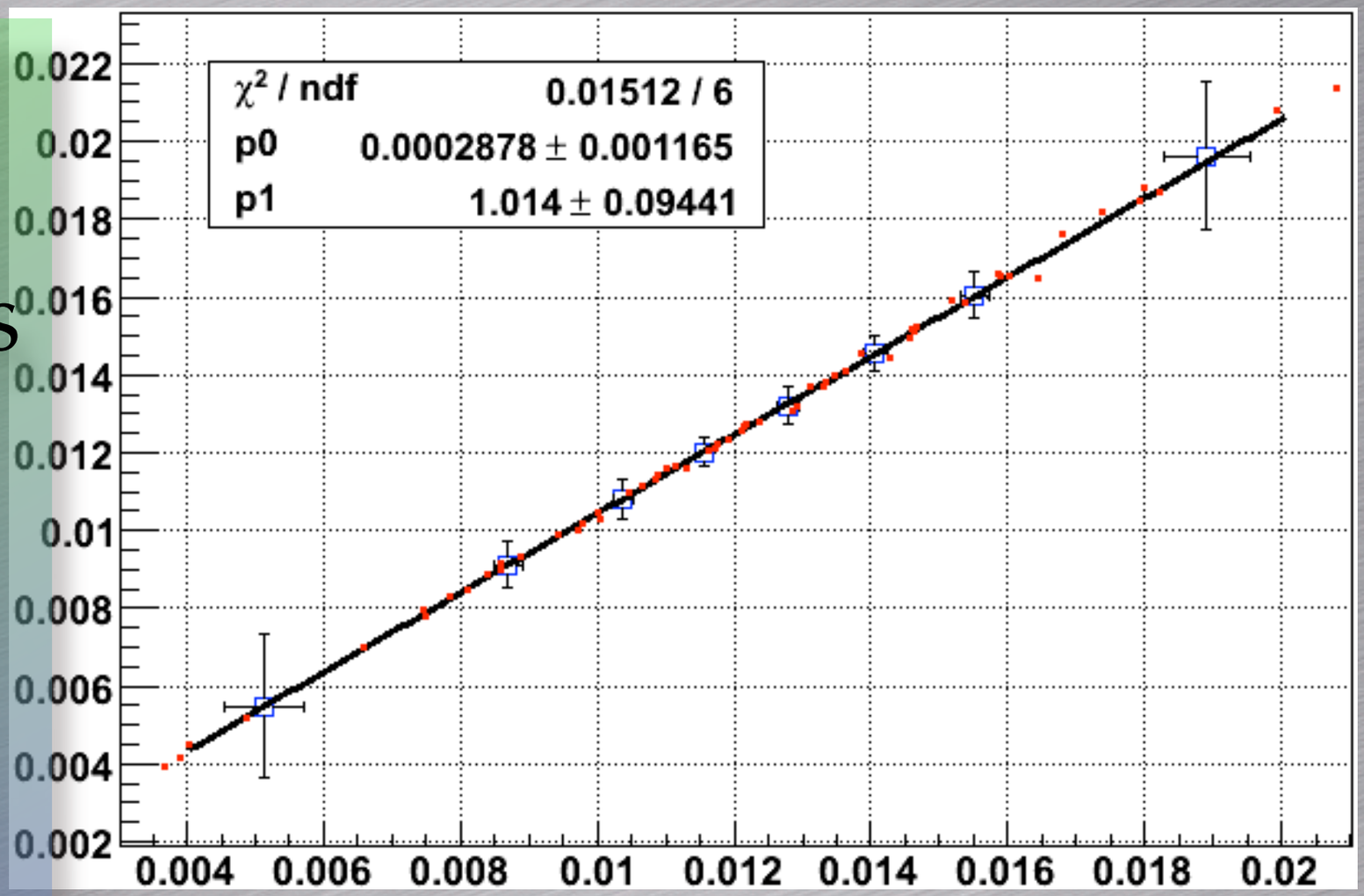


Ionization: Scalers

- Ionization is linear with scaler measures of luminosity
- Points out problem runs
- Now using 1-second averages

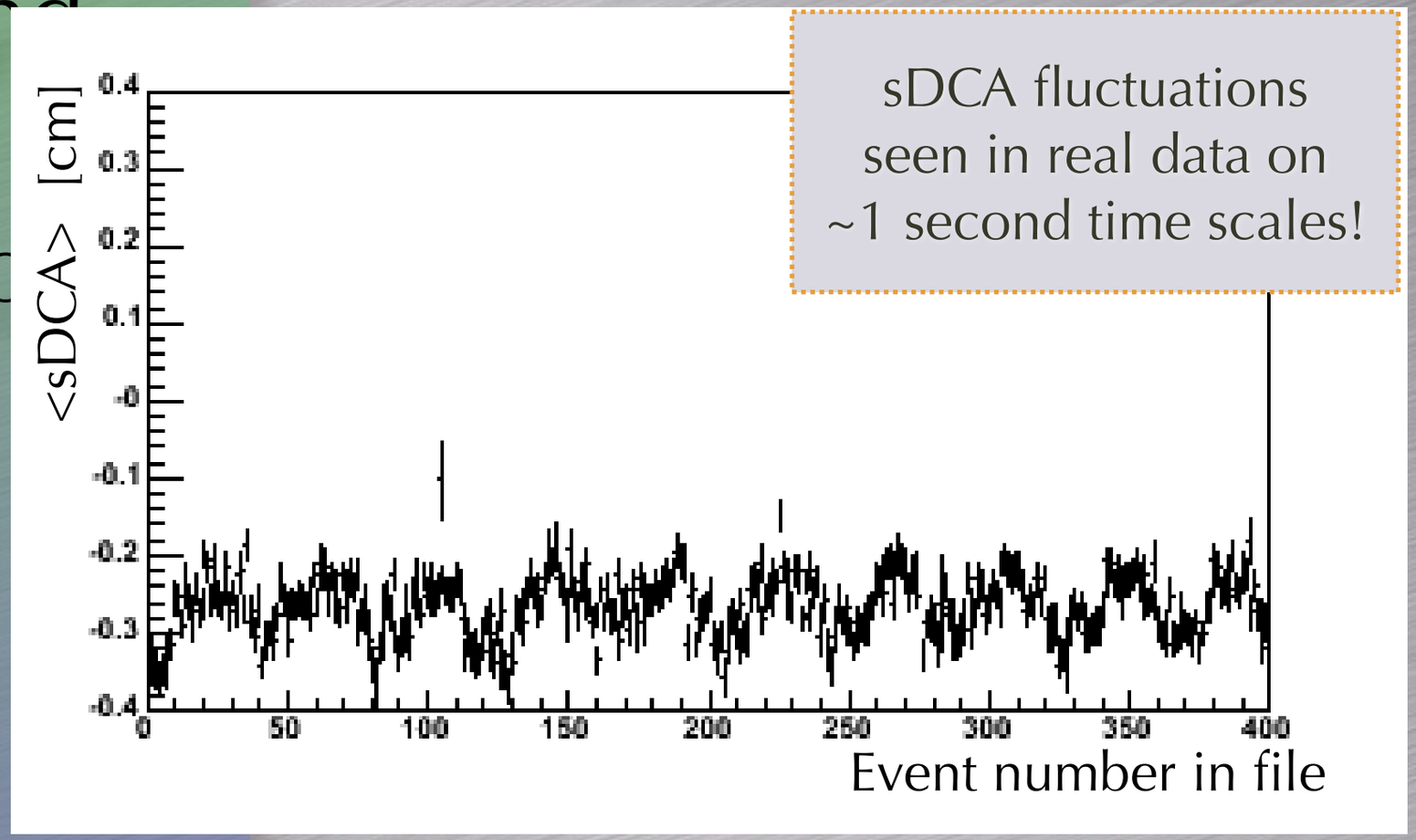


Luminosity = function(scalers)

STAR records scaler rates on Zero Degree Calorimeters (ZDCs) and Beam-Beam Counters (BBCs)

Volatility seen during AA

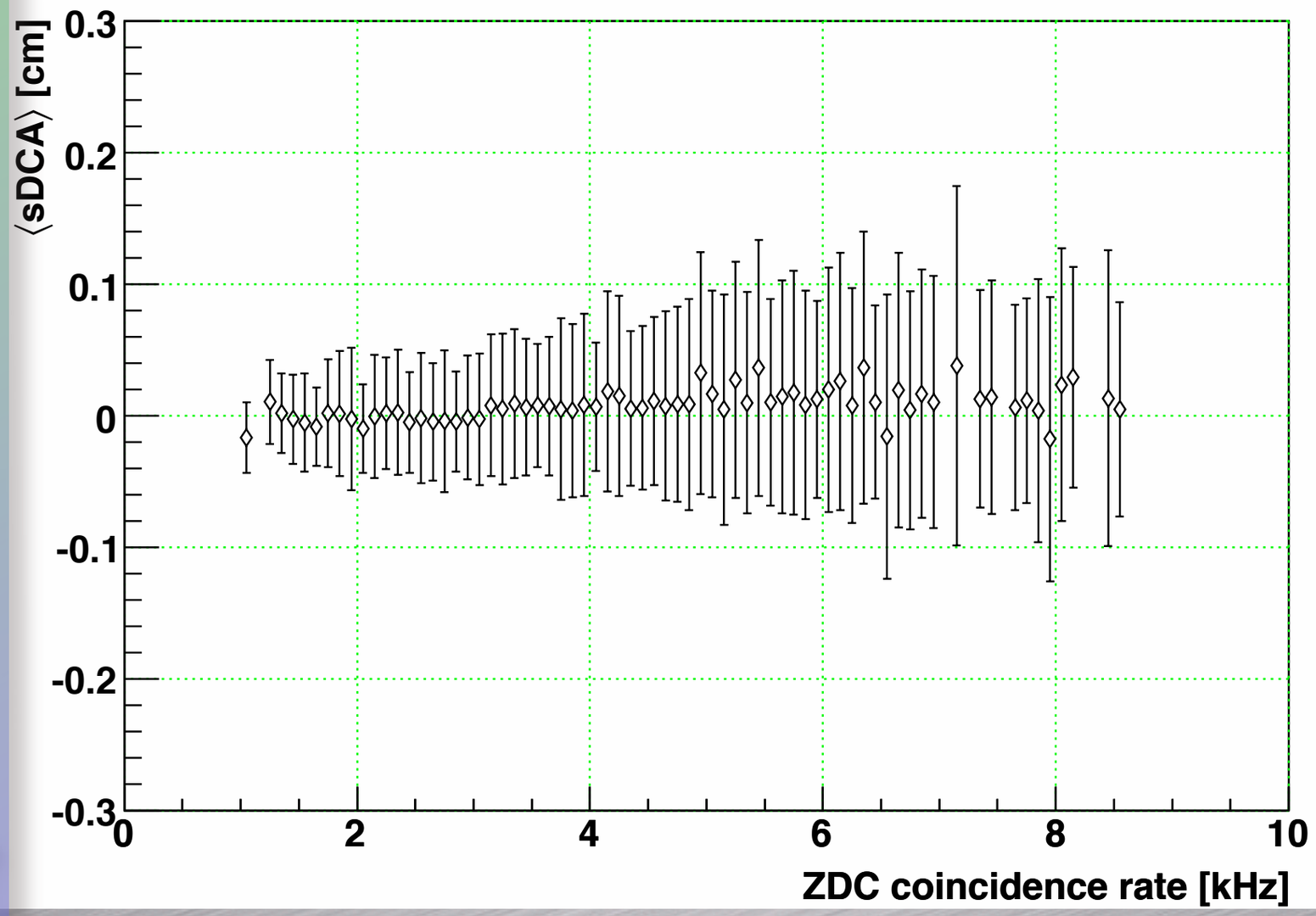
- Fluctuations seen on the 1-second time scale
- More discussio



Performance Measures: sDCA

- Can't beat low luminosity, but holding steady at high luminosity:
  - Spread from 5-9kHz appears roughly uniform
  - No indication we can't go higher!

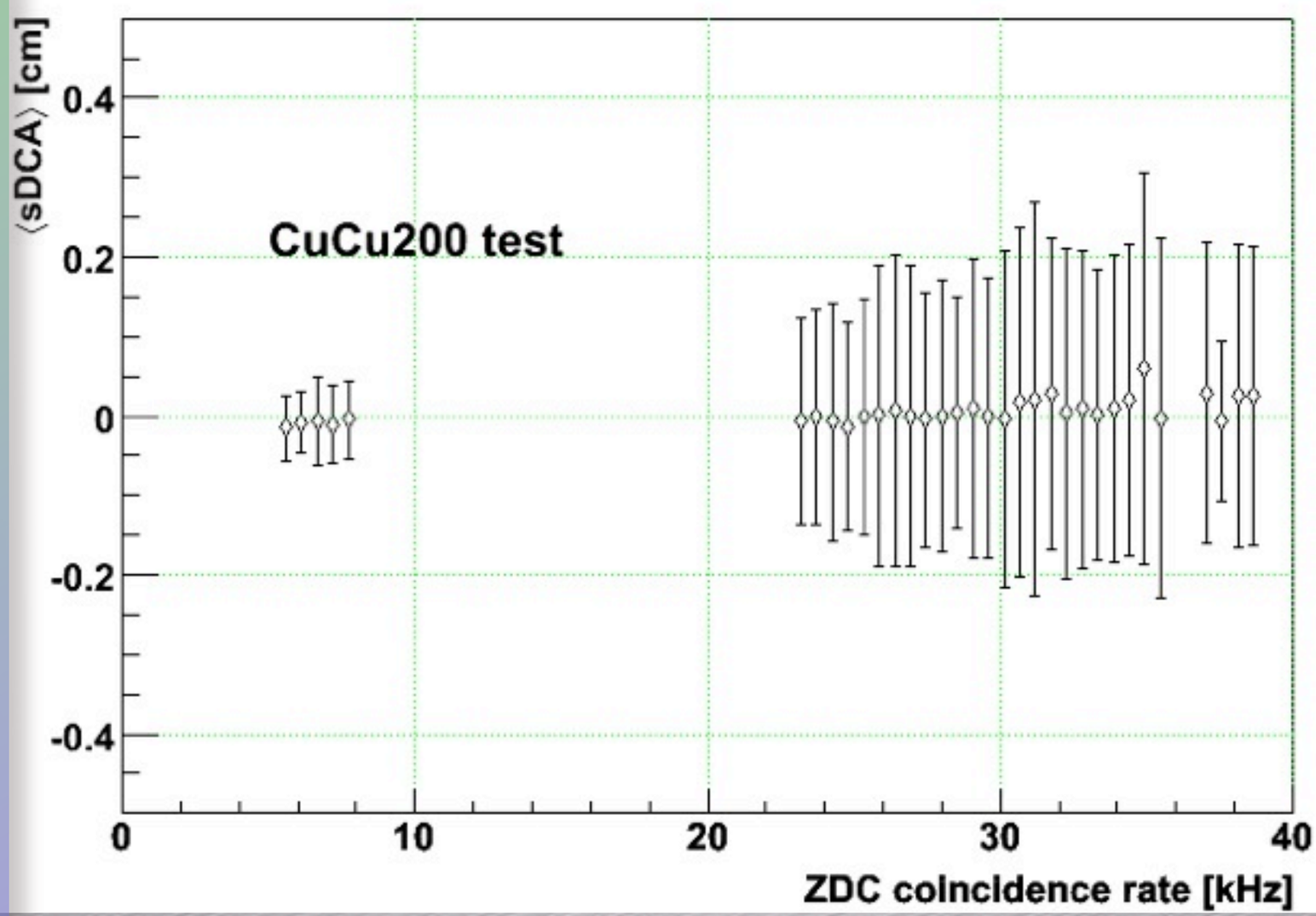
2004 AuAu at 200 GeV, all B fields



Performance Measures: sDCA

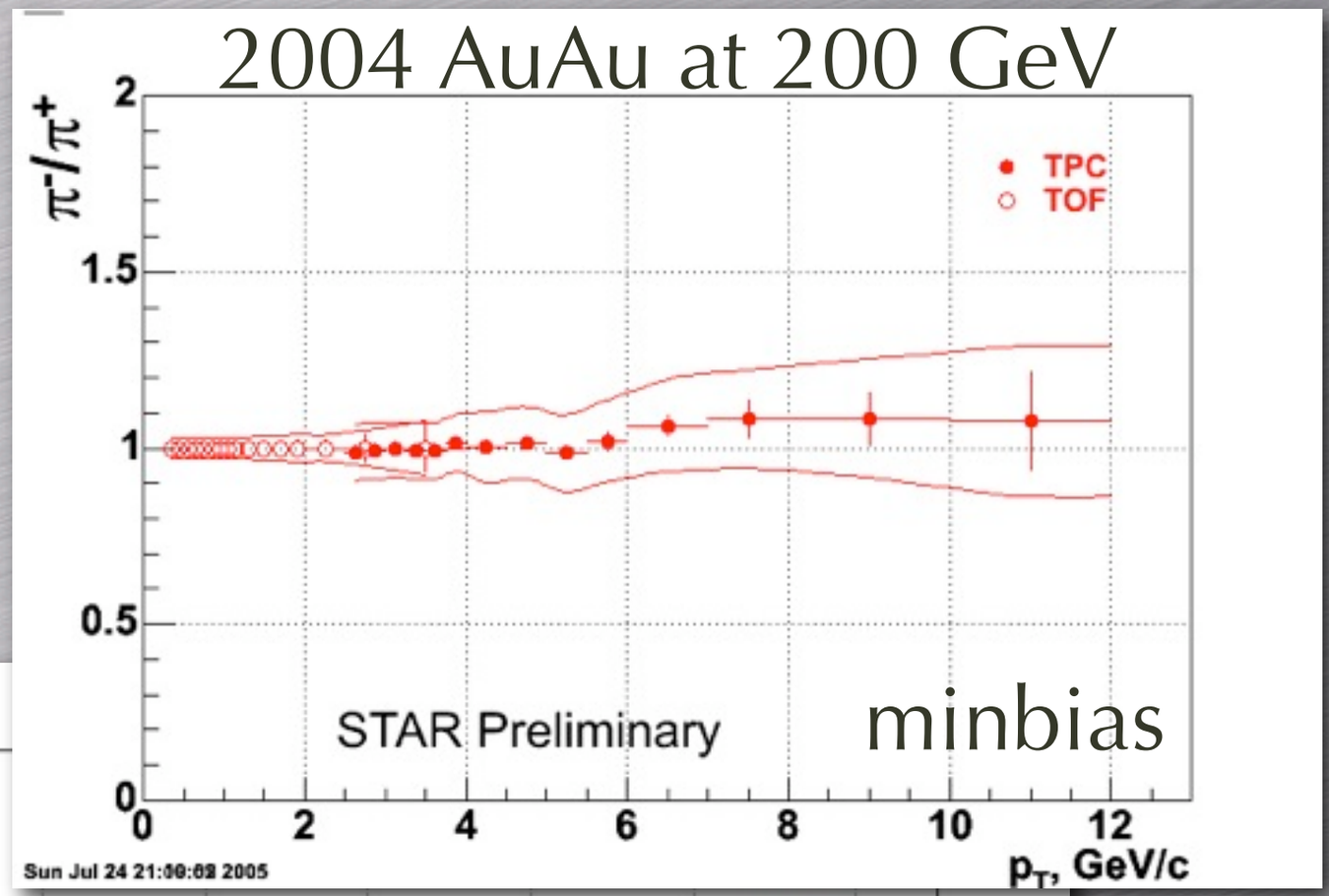
- Can't beat low luminosity, but holding steady at high luminosity:
  - E-by-E method performs worse due to statistics per unit time

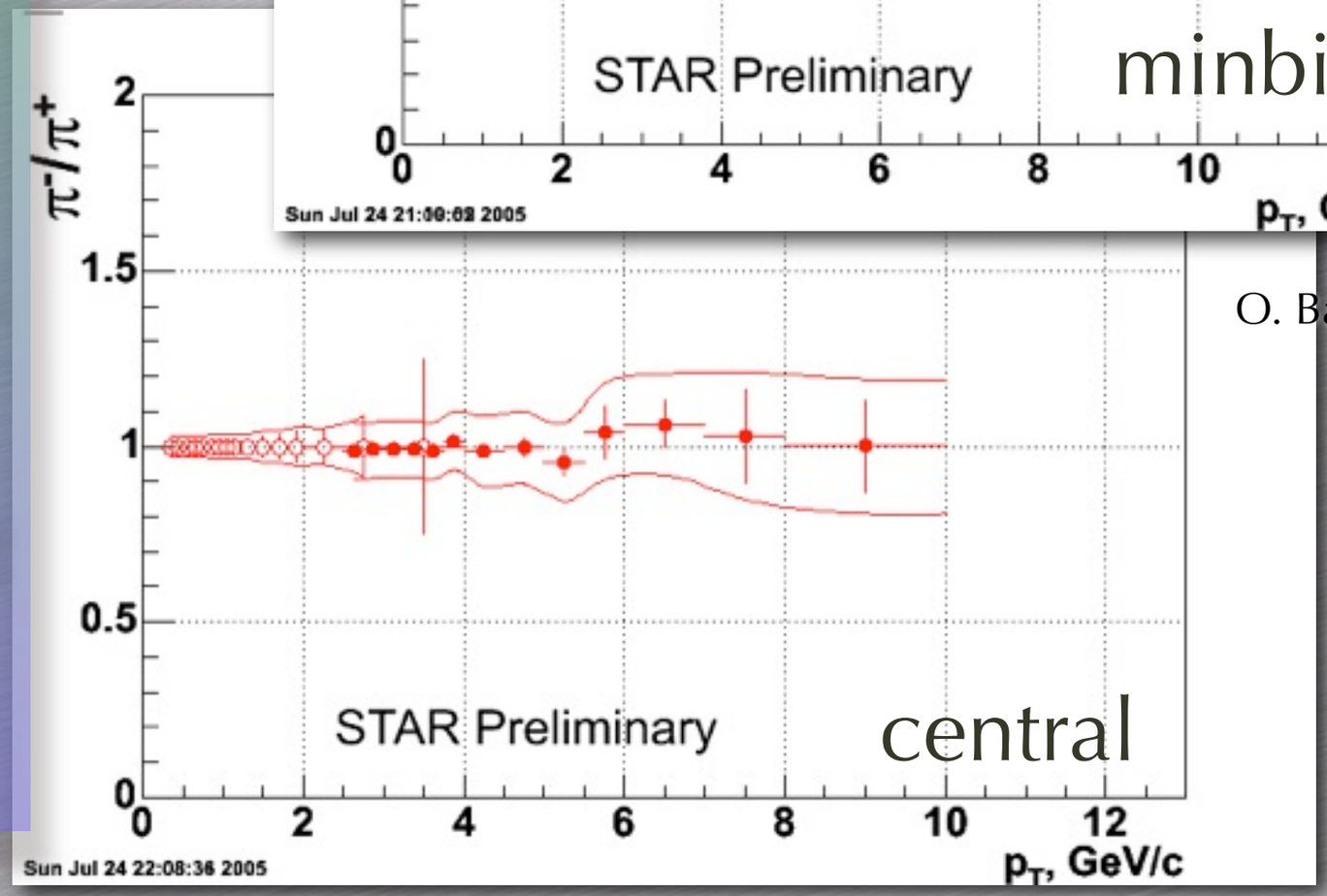
2005 CuCu at 200 GeV, full field



Performance Measures: π^-/π^+

- TPC-measure of the ratio essentially flat all the way to p_T=12 GeV/c !
- Central triggers (taken at high luminosity) just about as good!





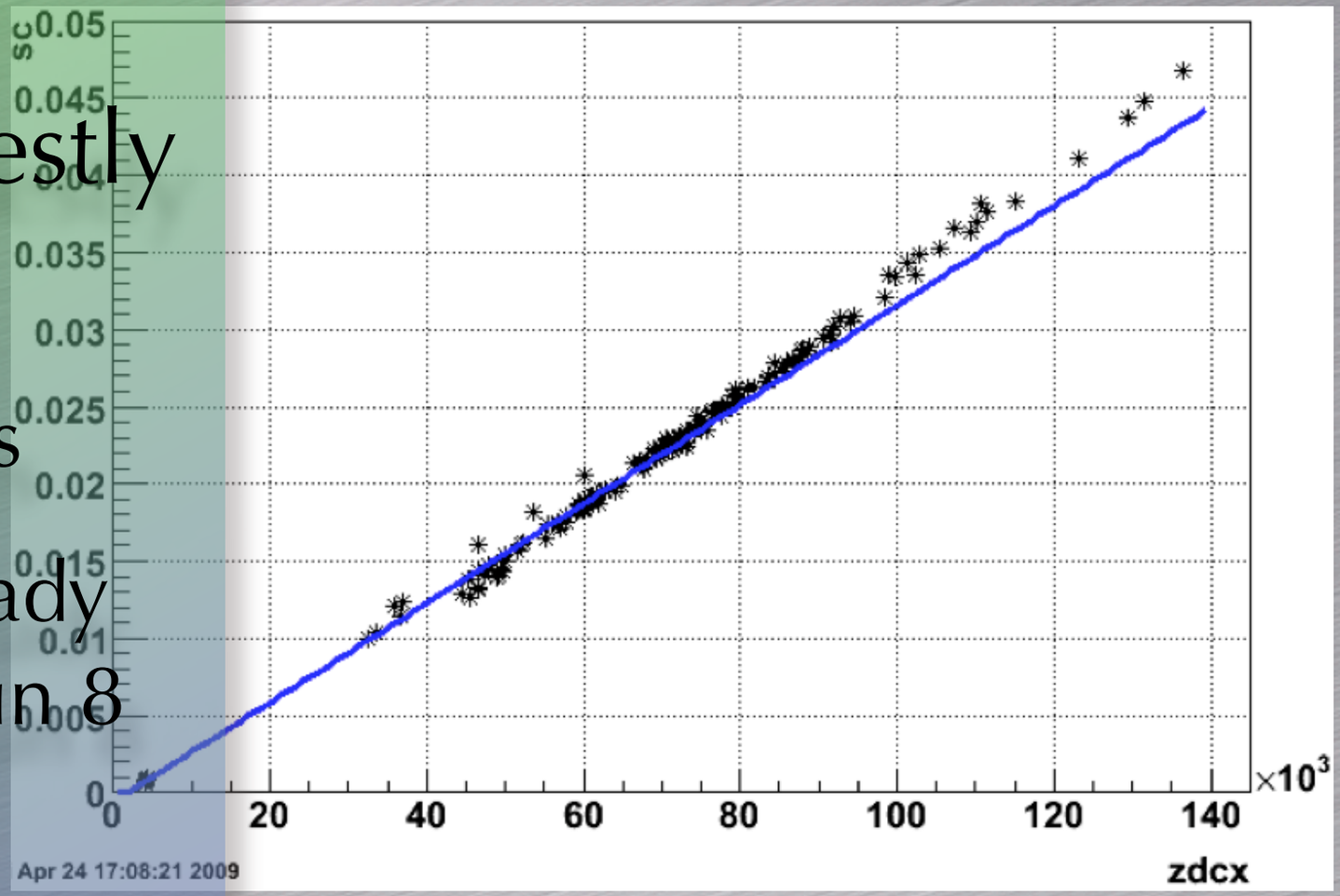
O. Barannikova

The Future: Up and Up (1)

- Higher luminosities
  - Can't even do tracking across TPC without some GridLeak correction
  - How close is our model to reality?
    - Differences will amplify with increasing luminosity.
    - How will the backgrounds change/grow/quell?
    - Not clear that the shielding has removed non-collision contributions
- pp500 has been a valuable test...

pp500: getting pretty high

- Preliminary calibration modestly successful
  - No major surprises
  - Non-linearity already encountered in Run 8 dAu 200 GeV.
- More Discussion



The Future: Up and Up (2)

- Higher DAQ rates
  - Increasing gating grid rates produced no notable change in SpaceCharge-like distortions(!)
  - Higher event rate *might* benefit the E-by-E approach
- Other techniques for SpaceCharge measures
  - Fixed detectors (GMT upgrade proposal)
  - Use identified pileup hits in the data (work in progress)

Back to the table...

- Analyses requirement: don't gain another √2
- What can we afford?
  - It is NOT the increasing distortions which hurt most, it is the increasing error of our understanding!
- Room to increase the error on our luminosity-dependent corrections
  - Hard to say what will happen...

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Our efforts are worthwhile!

- STAR TPC has major distortions with which we have been coping for years now (Physics produced!)
- Preliminary efforts appear successful with pp500, but we expect even higher luminosities and things could get worse for us
- We have some margin for further resolution error, but even small biases are problematic

Extras

Backgrounds

- Strong evidence for collider backgrounds: calorimeter backgrounds, "straight-through" tracking, zero-bias data, sDCA azimuthal distributions
  - Will shielding solve this problem for good?
  - Will we need to "map" the distortions?